Effectiveness of Assessment, Diagnostic and Intervention ICT Tools for Children and Adolescents with ADHD

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Abstract—The major technological leaps that have taken place over the last years, one of which is the creation and increasing use of ICT (Technology, Information and Communication), require a reconsideration of the capability of the computers to meet the expectations of modern education, especially in the field of Special Education. Researches confirm that new technologies offer liberating and amazing opportunities to people with disabilities, as these are not just limited to simple information management but can also operate supportively, improving the learning ability, the academic performance and functionality of the people that have special needs and those with special, educational needs. In this review there is a brief reference on some of the ICT assessment, diagnostic and intervention tools of the past decade, for children with attention and hyperactivity disorders (ADHD). It also refers to the direct connection and interaction between attention and memory capacity as well as, how, with the help of technology, we evaluate, improve memory, and thus attention. The deficit of ADHD in its executive functions and how these can be improved with the help of technology is also brought up in this review.

Keywords—ADHD, Executive Functions (EF), working memory (WM), assessment, diagnostic, intervention tools, Assistive Technology, Brain Computer Interface (BCI), Biofeedback/Neurofeedback, Natural User Interfaces (NUIs)

1 Introduction - Description of Attention Deficit Hyperactivity Disorder (ADHD)

Attention Deficit Disorder and Hyperactivity Disorder (ADHD) is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development. It is estimated that about 3% -7% of school-age children have ADHD [1]. However, according to several researchers, the percentage may range from 2.2% to 17.8% [2]. A similar variation in numbers is reported by Polanczyk et al. [3], ranging from 1% to 20% among schoolchildren aged 8-9. They interestingly point out that geographical and demographic determinants may be related to it. The same view is shared by Barkley in his survey [4], who also connects ADHD with gender, concluding that ADHD is more frequent and intense to boys rather than girls. ADHD is regarded as a neurodevelopmental disorder that affects a child's functioning on every

level (family, school, and social). Usually, the persons with attention-deficit disorder do not complete their duties and/or often avoid them. They have difficulty following instructions, focusing on the person that is talking to them and they quite often seem to lose personal belongings or other objects, thus showing disorganisation. Unceasing speech, anxiety and nervousness are prevalent. Their attention and concentration are easily disrupted by external environmental stimuli resulting to impulsive behaviour and unbiased mistakes [5]. Even the person's impulsivity manifests itself with the tendency to having difficulty in managing time and being impatient, interrupting others and/or answering questions without any consideration beforehand. In order to diagnose this disorder, the symptoms should occur frequently and last, at least for six months, from a very young age (3-6 years), being apparent both at home and at school. Consequently, there must be significant effects on functionality, on school, social and professional life, which most of the times are determined by the age of the individual. There are two different groups of symptoms. The first one focuses on the lack of attention and the second on the hyperactivity-impulsive behaviour. According to each person's symptoms, there are three different diagnostic categories that represent three types of ADHD respectively: A) ADHD that focuses mainly on the more "careless" kind of person (ADD), that shows signs of inattention with greater intensity and frequency, but no impulsivity and/or hyperactivity. B) ADHD that refers to the hyperactive-compulsive type (HD), when the symptoms of hyperactivity-impulsivity occur with greater intensity and frequency. In this category the attention problems are minimal. C) ADHD combined type, where the symptoms of distraction, hyperactivity and impulsivity manifest with the same intensity and frequency [1, 2].

2 Idiosyncrasy and Requirements of ADHD Students

Students with ADHD have always comprised a challenge for education systems, since their typical behaviour obstructs and restricts teaching in the traditional way. Inclusion in general classrooms is the common practice in most Western countries, therefore the need for differentiated teaching is mandatory. As stated by Loe and Feldman [6], children with ADHD are four to five times more likely to get involved with special educational programs and benefits than those of typical development. They are also more disposed to afternoon tutoring and remedial support. The aforementioned difficulties that a child with ADHD faces on a daily basis, usually result in poor school performance. Electronic distance learning tools can be used otherwise than initially designed and aimed at, as Fovet [7] indicates. Furthermore, as Wilkinson et al. [8] point out in their review, video games and off-line computer games have been of therapeutic value since the early 1980's, without overviewing the fact that restricted playing and interaction potential were offered. These restrictions have been surpassed by on line gaming offered on the internet, which is regarded as a means of transferring therapeutic practice. Especially concerning children with ADHD, they claim that these children tend to control their hyperactivity when they are occupied with motivating games, provided that they are not highly demanding in working memory. People with richer WM are proved to be more able to focus on complex

tasks, than those with lower WM capacity. This might mean that proper training of a person's WM should improve their ADHD condition. Shaw et al. [9] proved that a group of young teenagers with ADHD managed equal performance with the control group, at Conner's Continuous Performance Test 2, when it was presented as a video game, whereas, the equivalent performance at the traditional form of the test was inferior to the one of the control group [8].

According to Drigas and Ioannidou [10], education systems should create the appropriate conditions to improve learning and to ensure the transfer of skills and knowledge to pupils with special educational needs, such as students with ADHD. To achieve this, however, as recent researches and studies show, the contribution of new technology is needed. The integration of ICT into school helps the child with educational, social, and cultural difficulties, by giving them the experience they need through the virtual reality it creates. However, it should be extended to use at home, but also in society. ADHD is described as a multidimensional phenomenon which has to be taken into consideration along with other cognitive skills and executive functions [11]. It is indicated that all ICT procedures described in their article, have proved to be important to every function concerning attention, self-regulation, motivation, working memory and speech acquisition. At this point, all experts agree that Information and Communication Technology (ICT) gives the opportunity to all people with disabilities and special educational needs to have equal chances at learning, improving their daily routine, increasing self-protection and independence.

3 Assessment and Diagnostic Tools

Following the consensus, as cited in Sanches-Ferreira et al. [12], in order to effectively address ADHD, a multimodal approach, such as a combination of behavioural intervention programs, specialist and parental training, is needed. Sometimes, depending on the severity of the condition, these programs are either executed individually or with the use of appropriate medication. Also, cooperation between parents, teachers and specialists, dealing with the child with ADHD, is very important to cope with the symptoms and bring the child into the wider social environment. Usually, teachers and parents use body interventions that aim at suppressing the symptoms, rather than preventing them, from showing. This is why appropriate tools are needed to monitor an ADHD child in its interaction with the environment, so as to understand what the purpose or function of the problematic behaviour is and to get help when needed, through an intervention program. In the efforts to upgrade the way ADHD is monitored, there has been a tendency towards switching from the conventional ways of evaluating behaviour changes and instead using the more accurate and efficient mobile apps which will be available to parents and teachers.

A great example of such apps is the pioneering software called **"WHAAM"**. Its main focus is to comprise all the different behavioural aspects taken into account when attempting to paint a complete picture of a person’s conduct. In addition, it provides people that are involved into the ADHD person's care, with the ability to share with each other the proper way, to interact with the individual and also create a

productive mediatory plan [13]. WHAAM (WA) is accessible through both the web (PCs) and mobile devices (the mobile version is called "WMA"). A really important feature is the cross-platform communication that allows the two apps to share information. This network monitors the dysfunctional behaviours of the child at school and at home and shares information about the diagnosis, specific medication and schools that are suitable for the child. While the web version is aimed towards establishing the patient's profile by forming the network around him/her, gathering data and overall assessing their behaviour and adjusting the interventions accordingly, the mobile one (WMA), offers a much more direct approach. Given that mobile devices are at hand almost anytime and any-place, they can collect the data instantly, with a variety of ways such as ABC charts, thus making the app an extremely handy tool [13]. Moreover, the behavioural intervention plan will be a few taps away from every person that should need it, diminishing the chances of adults (teachers, parents, therapists) mishandling situations, where the child with ADHD might misbehave, or even having different approaches. This will also deal, to an extent, with the problems ADHD children face with their performance at school, which often leads to them dropping out early. WA also enables users to perform a functional evaluation that Horner describes as the use of "a set of strategies used to identify antecedents (those that preceded a negative behaviour) and consequences that control the problem behaviour" in order to reduce negative behaviours and replace them with positive ones [12]. In addition, the WA calculates the TAU-U statistical index for behavioural data collected by network members. The statistical index TAU-U estimates the magnitude of the effect of a treatment on unwanted behaviour [12].

Another example of computerised tools that help diagnose issues with a person's WM is the **Automated Working Memory Assessment (AWMA).** Alloway et al. [5] claim that it is rather difficult to identify probable working memory problems in classrooms, without using special screening tests or tools designed for this purpose. This standardised software allows not only specialists but teachers as well, to easily estimate someone's memory skills with its three level evaluation technique that tests verbal short-term memory, visual-spatial short-term memory, verbal and visual spatial working memory. It is also divided into Short form (AWMAS) for people suspected of having memory problems and Long Form (AWMAL) for people known to have such problems in order to make a confirmation**.**

Craven et al. [14] utilise **Urban Screens** as a means of support for communities and of creating new and collaborative observations concerning ADHD and its social "stigma". Their '**The Screens in The Wild (SITW)'** project of **Snappy App** was developed according to this frame of reference. They support the idea of using such platforms to increase public consciousness related with ADHD amongst others, referring to the use of serious games as a means of promoting healthy behaviours ("exergaming"). Initially, they integrated a psychometric Continuous Performance Test with an interactive application for smartphones, to enable the evaluation of the three prevalent symptoms of ADHD (i.e. inattention, impulsivity, hyperactivity). The procedure proved to be user friendly, moreover it resulted to the idea of its gamification as an Android smartphone App. The application, called Snappy App, provides the user with a contingent arrangement of letters of the alphabet, following the format of a typical

CP test ; the visual or auditory prompts (letters) are presented to the users , demanding response to the "target" and zero response to the "non-target". Subsequently, came the utilisation of the Web-app version of the Snappy App, into a "game Attention Grabber" on The Screens In The Wild platform (SITW), placing emphasis on the detection of impulsivity and inattention. The original app was then re-designed by using graphical objects such as fruit and other animations aiming at making it more tempting, whereas the web-app was forwarded on the urban screens. The research team aimed at play-testing the Game at the four Screens In The Wild locations existing in the UK, in order to evaluate it.

4 Intervention Tools

Symptoms of ADHD, such as poor attention skills and/or hyperactive and impulsive behaviour, can be observed early on a child's school life. Following the timely detection, the parents and teachers surrounding these kids are called to take cautious yet effective measures. The appropriate information, guidance and of course co-operation between these adults, can actually make the difference between an improved academic performance and an early drop out. ICT use in both regular and special education, is widely thought to not only upgrade the existing system and its components, but also implement new ones. Specifically, Cognitive Assistive Technologies (CAT) use a variety of tools such as smartphones with adapted applications, cognitive training games, audio books, voice recognition software, ear plugs, minimalistic learning environments and graphical user interface (GUI) adjustments [15]. CAT stimulate learners, draw their attention on specific tasks and help them retain it. As far as people with ADHD are concerned, studies have confirmed that the new age software will offer a whole other approach to the way diagnostics and interventions are carried out [16]. Researches indicate that computer-based activities seem to have a positive impact on a child's cognitive abilities. Especially children with ADHD are extremely benefited from these activities as these combine both acoustic and visual stimulation helping them to break down complicated meanings and comprehend them.

One of the first research teams who attempted to shed light into the abilities of children with ADHD when occupied with computer games, were Shaw et al. [9]. They chose computer games available in the market and standardised electronic tools that were initially designed to measure the executive functions in children with ADHD. A game-like version of the Conner's Continuous Performance Test 2 (CPT2) and two games, "The Revenge of Frogger" (set on a laptop) and "Crash Bandicoot 2" (set on a PlayStation console) were given to the children. Moreover, they presented a specially designed game-like adaptation of CPT2, called "The Pokémon Task". The involvement time for each of the games was fourteen minutes. When playing the Frogger, the player had to guide a frog through traffic pathways and a river, to the riverbank where it would rest safe. There was no option of swimming; instead, the player had to patiently wait until moving wooden chunks and river turtles appeared, in order to move the frog by using them. In a different case (moving in traffic or wading into the river), the frog lost a life. In the second game, Crash (the hero) had to be

transferred around the screen, to collect crystals and points. The movements had to take place in certain moments though, in order to be considered successful and gain points. The procedure of CPT2 was done as normally indicated, by asking the participants to press all the letters except for X. In the gamified version -The Pokémon Task-, the player had to catch as many Pokémons as possible, avoiding however to press on Pikachu, which had substituted the letter X. After the players were engaged in all the games, they showed a serious degree of reduction in impulsivity and spontaneous responses. They obviously made less errors when occupied with the Pokémon Task, compared to their performance at the traditional CPT2. Consequently, the initial estimation of Shaw et al. concerning error reduction due to impulsive action on the game-like activities, was confirmed. They agree, based on previous studies and experimentation, that computer games are highly motivating, enhancing effort and maintaining interest for children with ADHD. According to them, further research involving a bigger sample of children with ADHD is required, together with more specific research on the positive effect of computer games on the executive functions.

Children and adults with ADHD have the tendency to be more focused and concentrated when they are engaged with digital activities, especially gaming [17]. They overcome lack of motivation and appear to have a positive tendency towards these activities. After having realised the gap in the availability of game like training programs focusing on skills referring to daily life situations, Bul et al. developed a new serious game, called Plan-It Commander. The specific purpose of its design was to put forward behavioural learning and everyday life skills; namely managing time, being organised, making friends and other skills intended to promote social acceptance, in which children with ADHD often lag behind. The team conducted a research, the findings of which showed great satisfaction among the participants, after having been involved with the game. Plan-It Commander showed high potential of serving as a significant tool for intervention, in accordance with the rationale of its designers; notwithstanding, a clinical trial is still necessary to ascertain the degree of its efficacy.

Craven and Groom [18] present in their survey, three fields on which computer games and tests concerning ADHD focus: human activity in daily situations, education and medical practice. According to them, most of the existing software applies to executive functions with a view to improving them. Throughout their study, they redetermined that frequent gamers establish better cognitive functions compared to infrequent or non-gamers. They present and propose new games based on tasks that involve monitoring and improve both attention and inhibitory activity. The games were designed by incorporating key elements of Continuous Performance Tests and Go/No Go and Stop Signal Tasks. Specifically, they created “Awkward Owls” and “Wormy Fruit”. Certain differentiation to existing ones was made by designing colourful cartoon characters, thus making the games more appealing to children with ADHD, simultaneously aiming at training gaze control. Their research showed some potential of therapeutic intervention but they also suggest that further research should be carried out.

A central element of the concept of ADHD is the deficit in executive functions [19]. The executive functions include inhibition (self-control, self-regulation), design, working memory, reasoning, cognitive flexibility, problem solving. They are respon-

sible for deliberate, continuous, and directed behaviour towards a goal. The ADHD difficulties in organizing, managing time, and planning are due to executive functions deficits. While EFs improve, the difficulties burden the child's functionality and remain in adulthood. In order to improve EF, Weisberg et al. [19] designed TangiPlan, a set of tangible objects that represent the tasks that children with ADHD have to do in their morning routine. Parents together with children divide the morning tasks in smaller steps from the previous night. The next day, each item is placed in the room next to the work to be done. The child activates the item when it starts the job and turns it off when it is completed. At the same time, while the object is active, it also indicates the time spent doing the job, and this helps the child to manage time effectively. At the same time, TangiPlan is connected to a web-based interface, so parents watch through their mobile in real time the completion of the morning tasks by their children. In the future, it would be possible to improve the TangiPlan by giving detailed information about the time the child could spend on some work by collecting the child's performance data.

Chacko et al. [20] used "Cogmed" as a program for memory training (Cogmed Working Memory Training – CWMT). Cogmed is a computerized training program, designed to enhance working memory by increasing memory storage, aiming both at verbal and non-verbal aspects of it. The training takes place through a game-like computer interface. The training period lasted 5 weeks and there were offered 25 sessions, 5 per week. The participants were attended by coaches who provided support and reinforcement. Its efficiency was evaluated compared to a placebo version of it, in a sample of school-age children (7-11) with ADHD. The working memory of the participants was evaluated by using The Automatic Working Memory Assessment (AWMA) [5]. All families took part in a start-up session first, in which the characteristics of CWMT were presented. Then, together with the coaches, they were provided with a system of reinforcement and rewarding throughout the whole training session. After the training period, parents and teachers evaluated the program. They reported improvement in verbal and non-verbal working memory capacity. There was no evident improvement measuring verbal and non-verbal complex working memory (which involves both capacity and processing), or in other ADHD features such as attention, impulsivity and hyperactivity. Concerning academic performance, Chacko et al. [20] suggest longer term follow up evaluation. They also mention that, probably, because of methodological study restrictions, the extent to which CWMT offers positive results to training school children with ADHD is not certain.

Garcia-Zapirain et al. [21] claim that the learning ability of children with ADHD is enhanced through movement and gestures, so they experimented on a system that supports gestures and hand-eye coordination as well. They developed a technological platform with the use of "Net Framework". The aim was to support children with ADHD with their attention deficiency and to develop their learning ability, getting aid from two physiological sensors; namely "The Leap Motion" - a hand movement recognition sensor and the "Tobii X1 Light Eye Tracker". These wearable sensors are categorised into Natural User Interfaces (NUIs), which comprise Human-Computer interplay devices aiming at using skills that already exist, in order to provide reciprocal action with specific content. The users of this dual system had to perform mathe-

matical calculations on the surface of a digital flower (Math Flower Exercise). If the calculation had a correct outcome, the petals of the flower turned green, if not, they turned red. In this way the players-users were provided with immediate visual feedback. An audio feedback was available as well, as a beeping sound was heard at the choice of a petal. At the end of the procedure, the users were given two questionnaires to evaluate the system and the process. The results were unequivocal. The hand-eye coordination proved to be extremely conducive to raising and maintaining the users' attention to the given tasks; there was also an overall improvement at their performance. The gesture based interaction also proved promising as another option, different from the traditional math-solving process, offering the users great entertainment amongst the others. Garcia-Zapirain et al. [21] believe that the dual sensory pattern they experimented on, could serve as a successful basis for further games, exercises or puzzle activities, given that attention and learning ability were significantly improved.

Brain Computer Interface (BCI) is a system which uses transferred brain signals (via EEG), to enable the user to operate a peripheral device. Over the last years it has been used as an alternative therapeutic method for users with ADHD, especially children and adolescents, by providing guidance through feedback from the EEG. The main motivation for the development of BCI technology, as referred by X.Y. Lee et al. [22], was to enable patients suffering from amyotrophic lateral sclerosis to handle objects with the use of their brain, due to their limited kinetic ability. A second serious concern that gave a strong urge towards BCI technology was the realisation that children with ADHD receive a considerable amount of medication to cope with lapse in concentration, the side effects of which cannot be precisely estimated [22]. A feature which makes BCI technology fully user friendly is that it has no side effects and it is developed game-like so it retains a certain degree of motivation and benefit for each individual under training, who nonetheless, considers himself a player. We refer below to several scientific studies and experimentation on this field together with positive and promising effects on training attention to children with ADHD.

Based on existing biofeedback researches and relaxation techniques, Amon and Campbell [23] examined in their study whether the biofeedback tool “The Journey To The Wild Divine” would prove effective on managing ADHD symptoms. Three sensors were put on the players' fingers to discover variations in heart rate and skin transmission ability. These variations were transformed through the game into the necessary “pathways” to proceed and finish the game itself. Any frustration or raise of anxiety on behalf of the player would immediately delay or block the “pathway”, thus hindering the player from going on and finishing the game. Evidently, players with ADHD found out that only by being calm and concentrated they would proceed in the game. This realisation offered them a strong motive to participate in the whole game-like treatment. At the end of the study, questionnaires were given to the parents of all the children who took part in the survey. The parents of the experimental group (the children with ADHD) reported amelioration of breathing and relaxation techniques through the biofeedback video game. The outcome of their study, together with support from other biofeedback related researches, showed that The Wild Divine video game can potentially develop positive attitudes and behaviours of children and ado-

lescents with ADHD. However, according to Amon and Campbell [23], further research concerning long term effects of biofeedback needs to be conducted.

Having materialised a twenty session BCI attention with positive results on ADHD symptoms, Lim et al. [24] tested a new more demanding training game structure based on BCI again. They adopted EEG based biofeedback practices, to treat ADHD based on evidence that prevalent ADHD symptoms, especially inattention, can be successfully trained through BCI-based games. Their new training game system consisted of a headband with dry EEG electrodes connected to a computer via Bluetooth. The major gaming activity was the video game CogoLand, especially designed with 3D graphics for the purpose. The player is required to move an avatar with the help of signals transferred by the EEG electrodes. The proceeding rate of the avatar depends on the concentration level of the player. The game was developed in three levels, each demanding different task fulfilment from the avatar. This three level intervention program was carried out for eight weeks (three times per week), with a follow up of three monthly sessions. At the end of the sessions, the parents reported improvement in hyperactivity and impulsivity, as well as in attention. Moreover, the children who received extra monthly training sessions maintained these improvements. According to Lim et al. [24], BCI-based attention training through gaming systems has proved to be successful for children with ADHD.

The same gaming activity, CogoLand, was used by Qian et al. [25]. Based on recent studies which proved EEG based neurofeedback systems successful, they occupied themselves with a BCI-based attention training program, aiming at examining the extend of reorganisation of large-scale brain networks in children with ADHD. The evaluation of the program included RS-fMRI imaging and clinical assessment as well. The whole procedure lasted eight weeks with a rate of three sessions per week. The methodology used was one of a headband with dry EEG sensors connected to a computer via Bluetooth technology. The avatar of the game was powered by the player's attention, as in the previous study. The results that were extracted after the 8-week intervention period were positive, confirming that attention in children with ADHD was improved. This lead to brain network reorganisation and was connected with further behaviour improvement, since the salience processing system and the efficient regulation between goal directed and stimulus driven attention were brought close to normal standards. Qian et al. [25] present several advantages of BCI-based attention treatment, including safety in use, convenience in the procedure and the place of utilisation and no need for concurrent medical support. Despite the positive findings of their research, however, they agree that further studies are necessary to define to which degree the results of BCI-based treatment are permanent.

Another BCI system focusing on intervention to children with ADHD was developed by Rohani et al. [26]. They installed prototype games in a highly motivating Virtual Reality (VR) classroom setting, with reproduction and command of usual, everyday auditory and visual distractions. Two feedback games were used, each requiring precise and timely definition of relevant input. They were based on the P300 potential, ‘a large positive voltage in the recorded EEG peaking around 300ms after a cognitive attended rare stimulus’ [26], which is indicative of a person's attention or not. The first game, called “ANISPELL”, was based on the already existing P300

speller By Fawell and Donchin. It comprises sixteen animal images presented random-like, demanding for specific attention on one of the animals and providing information about it at the end of the procedure. The second game, called the "T-SEARCH", was created after taking inspiration from Frintrop et al. It consists of twelve different pictures presenting an amount of the English letters "X" and "T". They are presented random-like as well, in a rate of 5 per second. The player is asked to spot the blue "T" symbols and finally to select the correct classification square with all the blue "T" letters. Both games resulted in showing the effectiveness of P300 potential in measuring the attention of children with ADHD. Moreover, with the addition of the distractions in the virtual classroom, improvement through repetition and training was achieved. Rohani et al. [26] recommend to those who develop neurofeedback devices, the implementation of P300 potential and interactive BCI systems when focusing on ADHD therapeutic treatment.

5 Conclusion

As Visser et al. [27] report, one of the characteristic symptoms of ADHD is hyperactivity, which forces the child to get up many times from his place in the classroom. Barkley [4] also claims that deficiency in inhibition and self-regulation have turned out to be important foci in the theories concerning ADHD. Fortunately, with the help of ICT, the situation is changing as far as executive functions are concerned. The software relevant to each case and function, provides tempting and motivating stimuli given through audio-visual methods, while at the same time it improves the person's functionality in daily situations. By providing positive and/or negative feedback to the student, focus on the school duties is maintained. Over the last years, a lot of attention has been placed on the working memory (WM), the cognitive system responsible for behaviour amongst other functions, the level of which, if lower than average, can often be associated with ADHD. In cases of WM problems, timely recognition and therefore, intervention, is crucial. If parents act in time and accordingly, it can make the difference between later academic success and failure. WM training software can be efficient even at early stages, as we have come to realise throughout our review. Bringing our conclusions to an end, we have to make a special reference to Biofeedback and Neurofeedback BCI systems developed in the last decade, which have proved to be effective so far, on both training working memory and decreasing inattention.

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